

The effect of surface treatment on the interfacial reaction between Pd and p-GaN

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In recent years, nitrides such as GaN, InN etc, have drawn much interest as a promising material for the fabrication of efficient blue emitting devices, laser diode, and high temperature/high power electronic devices because they have direct wide band gap (3.4eV at R.T.) and a high saturation electron velocity (3×10^7 cm/s)[1-3]. As GaN device technology advances, more stringent demands will be made on the reproducibility, uniformity, thermal stability, and high temperature operation of the ohmic contacts to GaN-based devices[4]. For n-GaN, Al/Ti-based ohmic contacts have been used widely as an n-type ohmic contact and they showed extremely low contact resistance[4,5]. On the other hand, no satisfying ohmic contacts to p-GaN have been developed because the maximum doping concentration of p-GaN was restricted under 10^{18} cm⁻³ and there is no metal with a high work function comparable to the electron affinity of p-GaN. In order to obtain the low resistance p-type ohmic contact, various metal contacts were applied to p-GaN ohmic contact, such as Au, Ni, Ti, Pd, Pt, Au/Ni, Au/Pt, Au/Cr, Au/Pd, Au/Mg/Au, Au/Pt/Pd, Au/Cr/Ni, Au/Pt/Ni, Au/Ni/Pt, Au-Zn/Ni, Si/Ni/Mg/Ni etc[6]. Among those reports, Au/Pd contact system showed very interesting results that Au/Pd contact system showed ohmic characteristic even before annealing in spite of large theoretical Schottky barrier height[7].

In this study, we have investigated the surface treatment effect on the interfacial reaction of Pd/p-GaN interface and also the room temperature ohmic contact formation mechanism of Pd-based ohmic contact. In order to examine the room temperature ohmic behavior, various metal contact systems were deposited and current-voltage measurements were carried out. From the results of interface reaction between Pd and p-GaN, the polarity of p-GaN would be discussed.

GaN was grown epitaxially on (0001) sapphire substrate by metal organic chemical vapor deposition (MOCVD) and Mg-doped with the carrier concentration of about 4.4×10^{16} cm⁻³ and the electron mobility of 9cm²/Vs. All the metal layers were deposited by an electron beam evaporator without breaking vacuum and the base pressure was below 1×10^{-6} Torr. Prior to metallization, the samples were etched in aqua regia (HNO₃ : HCl = 1 : 3) or boiling aqua regia solution for 10min followed by DI water rinse to remove the possible native oxides. After surface treatment, the p-GaN was characterized by XPS(X-ray Photoelectron Spectroscopy). In order to evaluate the ohmic characteristic, I-V measurement was carried out between two front surface circular contacts and all the contacts were patterned during deposition using stainless steel shadow masks and the contact resistance was measured using the circular TLM(Transmission Line Method). The interspacing of metal contacts (0.5mm diameter) was 0.5mm. The synchrotron x-ray scattering measurements were carried out at beamline 5C2 at Pohang Light Source (PLS) in Korea. The incident x-rays were focused vertically by a mirror.

In order to examine the surface of p-GaN surface, XPS analysis was carried out after surface treatment. Table 1 shows the relative surface Ga-to-N ratio for different surface treated GaN. Compared to the as-received p-GaN surface, Ga-to-N ratio was decreased after dipping in boiling aqua regia. In order to investigate the surface stability, AES depth profiles were carried out for Au/Pd/p-GaN after annealing at 600, 700, 800 °C. Au(1000 Å)/Pd(300 Å) contact were deposited on p-GaN after surface treatment and then the samples were annealed at elevated annealing temperature. Au/Pd contact was selected because of good reactivity with p-GaN. As shown in figure 2, p-GaN, which was dipped in aqua regia solution, started to react with Pd after annealing at 700 °C. After annealing at 800 °C, the interface reaction between Au/Pd and p-GaN was clearly shown and the Ga diffused out remarkably. On the other hand, p-GaN dipped in boiling aqua regia, the distinct interface between Au/Pd and p-GaN was sustained at 800 °C. Pd and Au have good reactivity with Ga and they did not reacted with N. The heat of formation of all the Pd-N binary system is all positive values and those of Pd-Ga binary system is as low as -33~79KJ/mole · atom[8]. From the fact

that interface stability of Pd/p-GaN upto 800 °C and decrease of Ga to N ratio, the surface of p-GaN was N-terminated after dipping in boiling aqua regia.

REFERENCES

1. H. Morkoc, S. Strite, G. B. Gao, M. E. Lin, B. Sverdlov and M. Burns, J. Appl. Phys. 76, 1363 (1994).
2. Shuji Nakamura, J. Vac. Sci. Technol. A 13(3), 705 (1995).
3. K. Suzue, S. N. Mohammad, Z. F. Fan, W. Kim, O. Aktas, A. E. Botchkarev and H. Morkoc, J. Appl. Phys. 80(8), 4467 (1996).
4. Y.-F. Wu, W.-N. Jiang, B. P. Keller, D. Kapolnek, S. P. Denbaars, U. K. Mishra and B. Wilson, Solid-State Electronics 41(2) 165 (1997).
5. D.-W. Kim, H. K. Baik, C. Y. Kim, S. W. Kim, C. H. Hong, Mat. Res. Soc. Symp. Proc. 482, 1083 (1998).
6. J.-K. Ho, C.-S. Jong, C. C. Chiu, C.-N. Huang, C.-Y. Chen and K.-K. Shih, Appl. Phys. Lett. 74(9), 1275 (1999).
7. J.-L. Lee, M. Weber, J. K. Kim, J. W. Lee, Y. J. Park, T. Kim and K. Lynn, Appl. Phys. Lett. 74(16), 2289 (1999).
8. R. Pretorius, T. K. Marais and C. C. Theron, Material Science and Engineering, 10, 1 (1993).

Table 1. Ga/N ratio of p-GaN after surface treatment.

	As-received	HCl treated	Aqua Regia	Boiling aqua regia
Ga/N ratio	1	0.9334	0.9300	0.9097

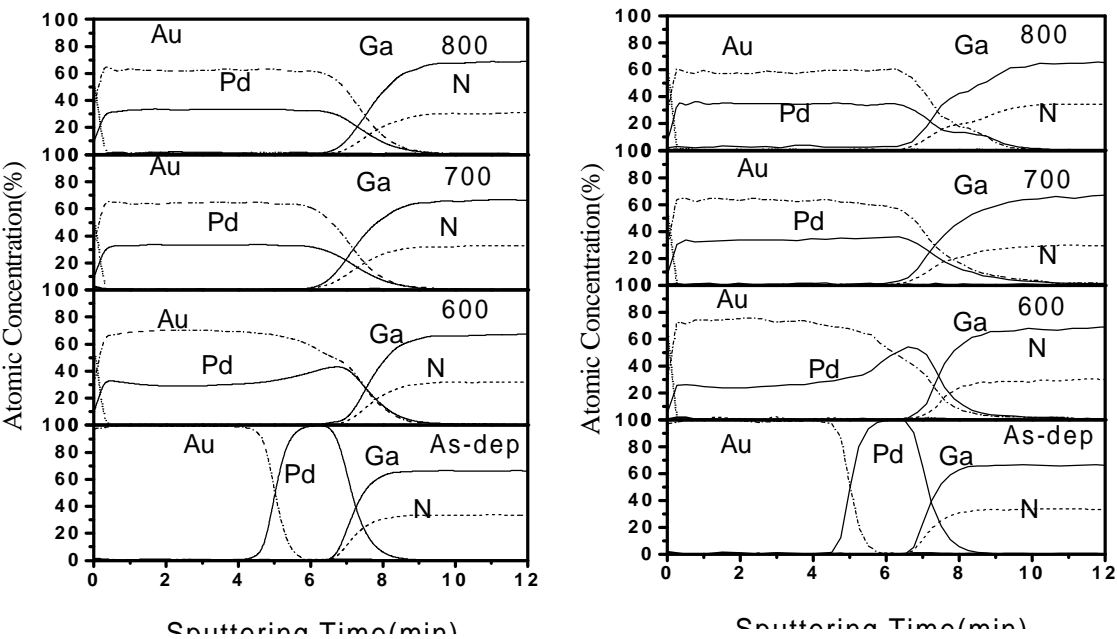


Figure AES depth profiles of Au/Pd /p-GaN before and after annealing at 600, 700, 800 °C .
 (a) Boling aqua regia treated p-GaN (b) aqua regia treated p-GaN